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KYANITE AND RELATED MATERIALS

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Kyanite output in the United States was an estimated 90,000 metric tons (t) in 2005; the United States was the world's leading producer of this mineral (table 3). Production of synthetic mullite in the United States was an estimated 40,000 t. There was no reported U.S. production of sillimanite. Andalusite was mined and marketed as part of a mineral mixture in the United States, but data are withheld to avoid disclosing company proprietary data. Refractory products continued to be a major end use for kyanite and related materials.

This report includes information on kyanite, andalusite, and sillimanite (all of which have the formula Al_2SiO_5) and mullite (Al_6SiO_{13}). Mullite is an aluminosilicate mineral that occurs in nature, although rarely, and also is made by calcining other minerals, such as kyanite. Synthetic mullite in this report refers to mullite that is made by calcining at high temperature certain alumina- and silica-containing minerals other than kyanite, such as bauxite and kaolin.

Production

Kyanite Mining Corp. (KMC), the sole U.S. producer of kyanite and kyanite-derived mullite, operated two open pit mines in Buckingham County, VA, and beneficiated the ore into a marketable kyanite concentrate. The company also had two kilns at its Dillwyn, VA, facility for production of mullite. Reported U.S. production data collected by the U.S. Geological Survey (USGS) are withheld to avoid disclosing company proprietary data. Estimated U.S. kyanite production in 2005, based on nongovernment estimates from previous years, was about 90,000 t with a value of about $13 million. KMC calcined some of its kyanite in excess of 1,450° C to yield mullite, a refractory (heat-resistant) material. KMC's mullite product contained about 80% mullite (Kyanite Mining Corp., 2006§[1]). Synthetic mullite, made from calcined bauxitic kaolin and sold by C-E Minerals, Inc. contained 87% mullite and was produced near Americus, GA (C-E Minerals, 2006§). Estimated U.S. production of synthetic mullite was about 40,000 t in 2005 (Dickson, 2006§); the estimated value for the material was about $9.7 million.

Piedmont Minerals Co., Inc. in Hillsborough, NC, mined a deposit containing andalusite combined with pyrophyllite and sericite. The company sold products containing blends of the three minerals to producers of refractories and ceramics.

Consumption

Kyanite increases in volume by 16% to 18% when calcined to mullite and can be used in its raw concentrate form in a refractory mixture to offset the shrinkage on firing of other components, especially clays. Mullite is abrasion- and slag-resistant. It also has good creep resistance, which is resistance to physical deformation under load at high temperatures. Andalusite expands irreversibly by only about 4% to 6% when calcined and can therefore be used directly in refractories in its raw state. The small-volume increase can be beneficial; calcining the refractory in service can result in tight-fitting refractory linings (Spears, 2005; Dickson, 2006§). In other refractory applications, kyanite concentrate is calcined to mullite before being added to refractory mixes if the volume increase of the kyanite is not required in the mix (Roskill Information Services Ltd., 1990, p. 56).

Examples of refractories that contain andalusite, kyanite, and/or mullite include insulating brick, firebrick, kiln furniture, refractory shapes, and monolithic refractories (made of a single piece or as a continuous structure) including castables (refractory concrete), gunning mixes, mortars, plastics, and ramming mixes. The interlocking grain structure of andalusite, kyanite, and mullite gives added mechanical strength to refractories and other nonrefractory ceramic articles. Other end uses of kyanite and related materials include brake shoes and pads, electrical porcelain, foundry use, precision casting molds, sanitaryware, and other products (Kyanite Mining Corp., 2006§).

Monolithic refractories are a major end use of kyanite (Kyanite Mining Corp., 2006§). Monolithic refractories are supplied in unfired, generally unshaped form in contrast to prefired, preshaped brick products. They include a wide variety of products that may be gunned, hand packed, moulded, poured, pumped, rammed, or vibrated into place. Monolithic refractories are used in many of the same consuming industries as brick, including aluminum furnaces, foundry (both ferrous and nonferrous), incineration, iron and steel production, petrochemicals, power generation, and other applications (Moore, 2004).

Iron and steel production continued to be the leading user of refractories worldwide. U.S. crude steel production decreased by about 6% in 2005 from that of the previous year. World crude steel production increased by 5.8% in 2005 compared with that of 2004 (International Iron and Steel Institute, 2006§).

Foreign Trade

The United States exported kyanite and mullite to countries in Europe, Latin America, the Pacific rim, and other areas. More than one-third of U.S. kyanite output was exported (Dickson, 2006§). Most of the material imported into the United States in 2005 was from South Africa and was presumed to be andalusite (table 2). No U.S. imports of kyanite or sillimanite were reported in 2005.

[1]References that include a section mark (§) are found in the Internet References Cited section.

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South Africa continued to be the leading producing country of andalusite, with an estimated 235,000 t in 2005. France produced an estimated 65,000 t of andalusite. Although the USGS has not obtained official production data, China appears to be a producer of kyanite and related minerals (Dickson, 2006§). Using available data, India has been the predominant producer of sillimanite, with an estimated annual production of 12,000 to 14,000 t in recent years.

Countries that are said to be producers of mullite (sintered mullite and/or fused mullite) include Brazil, China, Germany, Hungary, and Japan (Taylor, 2005b).

China.—China was the leading steel producer with about 31% of the world's crude steel production in 2005 (International Iron and Steel Institute, 2006§). It was also, by far, the leading producer of refractories (Semler, 2006§). China's refractory industry comprises a number of relatively small local producers and some larger companies. Many purchasers of refractories in China typically bought the cheapest usable product possible. However, this attitude was beginning to change, with steel producers willing to accept higher priced refractory products that are higher performing and longer lasting. This results in cost benefits to their own operations (Taylor, 2005a). Continued growth in the Chinese steel industry could result in higher kyanite usage (Dickson, 2006§).

India.—India's long coastline has large deposits of beach sands that contain heavy minerals, including sillimanite. Separation and beneficiation steps can be carried out on the sands to obtain various minerals. Extensive research is being carried out for utilization of these minerals; for example, mullite aggregate was developed by reaction sintering of sillimanite sand and calcined alumina. Also, high-alumina bricks and high-temperature insulating bricks have been developed from sillimanite sand. Another potential application of the sand is in ceramic fibers, which are used as insulating material (Banergee and Banergee, 2005).

India's iron and steel and cement producers are core refractory consumers and are projected to be key sectors in the country's economic and industrial development. India's refractory sector has experienced strong growth, and there has been a trend toward increased monolithic refractories usage. A notable example of this usage is in Indian sponge iron production (Taylor, 2005a).

India relies heavily on imported refractories and refractory raw materials. In order to improve domestic product quality and keep costs down, consideration could be given to development of domestic mineral sources and processing capability to upgrade raw materials (Taylor, 2005a). Local demand for refractories could increase significantly in the future, giving incentive to further develop domestic resources to supply this growth (Dickson, 2006§).

Outlook

The use of monolithic refractories continues to increase worldwide compared with the use of bricks and shapes. This is a result of advances in installation and repair, lower price, continued improvement of the products, and environmental benefits. However, bricks and shapes still perform best in some applications. The refractories industry continues to evolve and respond to changes caused by globalization, especially the associated major increase in competition, decreasing refractories consumption by user industries in some market areas, and increased raw material and energy costs. China is the leading producer of both refractories and steel. It is projected to continue increasing production of both commodities (steel manufacturing is the leading use of refractories). The increasing consumption of refractories that began in the United States in 2004 is predicted to continue until 2009 (Semler, 2006§).

References Cited

Banergee, G., and Banergee, D., 2005, Beach sands for refractories: Industrial Minerals, no. 451, April, p. 48-51.

Moore, Paul, 2004, Refractory monolithics: Industrial Minerals, no. 445, October, p. 43-49.

Roskill Information Services Ltd., 1990, The economics of kyanite 1990: London, United Kingdom, Roskill Information Services Ltd., 118 p. plus appendices.

Spears, D.B., 2005, Sillimanite minerals: Mining Engineering, v. 57, no. 6, June, p. 54-55.

Taylor, Lindsey, 2005a, Asian refractories steeled for change: Industrial Minerals, no. 456, September, p. 40-45.

Taylor, Lindsey, 2005b, Clays on fire: Industrial Minerals, no. 458, November, p. 30-39.

Internet References Cited

C-E Minerals, 2006, Mulcoa® calcines, accessed April 7, 2006, via URL http://www.ceminerals.com.

Dickson, Ted, 2006, Sillimanite minerals, Countries and Commodities Reports, accessed March 17, 2006, via URL http://www.mining-journal.com.

International Iron and Steel Institute, 2006, 2005 (full year) crude steel production, Press Release, accessed February 7, 2006, via URL http://www.worldsteel.org.

Kyanite Mining Corp., 2006, Virginia Mullite™ is very low in impurities compared to other traditionally sintered mullite, accessed March 6, 2006, at URL http://www.kyanite.com.

Semler, C.E., 2006 (January 11), Refractories review, Industry Snapshot, accessed January 20, 2006, via URL http://www.ceramicindustry.com.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Kyanite and Related Minerals. Ch. in Mineral Commodity Summaries, annual.

Kyanite and Related Minerals. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Other

Kyanite and Related Minerals. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Kyanite, Andalusite, Sillimanite, and Mullite. Ch. in Industrial Minerals and Rocks (7th ed.), Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, S.T., eds., Society for Mining, Metallurgy, and Exploration, Inc., 2006.

TABLE 1
PRICE OF KYANITE AND RELATED MATERIALS IN 2005

(Dollars per metric ton)

	Price
Andalusite, free on board, Transvaal, South Africa, 57% to 58% alumina, 2,000-metric-ton bulk lots	212-248
Kyanite, USA, ex-works, calcined (mullite), 54% to 60% alumina, 18-ton lots	248-295

Source: Industrial Minerals, no. 459, December 2005, p. 71.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE, KYANITE, AND SILLIMANITE[1, 2]

Year	Quantity (metric tons)	Value[3] (thousands)
2004[4]	4,010	$1,420
2005[5]	6,300	2,410

[1]Harmonized Tariff Schedule of the United States code 2508.50.0000.
[2]Data are rounded to no more than three significant digits.
[3]Customs value.
[4]Most material is andalusite from South Africa.
[5]No kyanite or sillimanite imports were reported.

Source: U.S. Census Bureau.

TABLE 3
KYANITE AND RELATED MINERALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country and commodity[3]	2001	2002	2003	2004	2005
Australia:					
Kyanite	1,000	1,000	1,000	1,000	1,000
Sillimanite[4]	100	300	300	300	300
Brazil, kyanite	600	600	600	600	600
China, unspecified	3,150	3,200	3,200	3,300	3,400
France, andalusite	65,000	65,000	65,000	65,000	65,000
India:					
Kyanite	5,500	6,000	6,000	6,200	6,800
Sillimanite	13,000	14,000	14,000	14,500	15,000
South Africa, andalusite	193,225 [5]	165,087 [r, 5]	164,921 [5]	234,625 [r, 5]	235,000
Spain, andalusite	2,500	2,500	2,500	2,500	2,500
United States:[6]					
Kyanite	90,000	90,000	90,000	90,000	90,000
Mullite, synthetic	40,000	40,000	40,000	40,000	40,000
Zimbabwe, kyanite	9,682 [5]	5,657 [5]	745 [5]	210 [r, 5]	--

[r]Revised. -- Zero.
[1]U.S. and estimated data are rounded to no more than three significant digits.
[2]Owing to incomplete reporting, this table has not been totaled. Table includes data available through March 17, 2006.
[3]In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.
[4]In addition, about 7,000 metric tons of sillimanite clay (also called kaolinized sillimanite) that contains 40% to 48% Al_2O_3 is produced.
[5]Reported figure.
[6]Source: Dickson, Ted, 2006, Sillimanite minerals, Countries and Commodities Report, accessed March 17, 2006, via URL http://www.mining-journal.com.